ated to profit by cooperation in research. In both countries national movements for the promotion of research are in progress and important advances are being made. The example set by the Canadian government in establishing the Honorary Advisory Council for Scientific and Industrial Research and that of the Royal Canadian Institute in organizing this series of addresses on research and its applications, have stimulated and encouraged us in the United States. The friendly bonds that have joined the two countries in the past have been greatly strengthened by the war, and I am sure that our men of science will welcome every opportunity to cooperate with yours in common efforts to advance science and research.

GEORGE ELLERY HALE

GENERAL CHEMISTRY AND ITS RELATION TO THE DISTRIBUTION OF STUDENTS' SUPPLIES IN THE LABORATORY

THE object of the general chemistry laboratory is, I take it, to teach chemistry. Its mechanical aspect is clearly a business on a par with any other undertaking that has a special object in view. True, the methods will differ somewhat from other endeavors, but the main idea of striving "to put across" a definite proposition puts the laboratory side of teaching chemistry on a straight business basis, and subject to the ordinary rules of business. Now a business firm no matter what the character of its work, knows that if they are to compete with others, they must avail themselves of every method, scheme or device that will cheapen production, facilitate transportation, add to the efficiency of their employees, or in any other way make better goods at a lower price than the competing firm. They are ever on the watch for a new idea and many dollars' worth of machinery are often scrapped to give place to a newer and more efficient machine. Many firms employ efficiency experts constantly seeking to improve or save anywhere and everywhere throughout the works. No progressive firm ever stands still, but is ever changing its methods for better ones. This does not seem to be true always in the conducting of a chemical laboratory. What "Bunsen did" many years ago is good enough now, and the old song, "the old time religion is good enough for me" seems to apply very appropriately to the management of many laboratories.

Such a state of affairs should not be, and these laboratories with unchanging methods will go to the wall as surely as will a business house run on similar ideas.

A recent questionnaire sent to a large number of institutions in all parts of this country reveals the fact that general chemistry is regarded as the most important and vital course in the department. The grade of work done in all other courses is determined by the nature of this course. If it is poorly given, all other courses are built on a poor foundation, and a poorly trained chemist is the result. The importance of this course is further brought out by this questionnaire, when we note that the number of laboratory hours in general chemistry varies from six to eight per week, for one year. In some cases this is in addition to a year of physics and chemistry in the high school. This, in many cases means that a student before he can take qualitative analysis in college has had in the high school one year of chemistry of say five hours a week for forty weeks, which makes a total of two hundred hours. In college, he has two laboratory afternoons of three hours each and three or four recitation hours a week for a year of thirty weeks, which amounts to 270 hours as a minimum. In other words, the student has had 200 hours in high school and 200 hours in college, or a total of 470 hours, exclusive of all home study both in high school and college. A few years ago these same institutions gave only five hours a week to general chemistry, but the growth of chemistry in this country has demanded a correspondingly increased preparation of students (on the part of institutions) and a very generous response has been given all over America. This increased preparation has been made possible by putting into the students earlier and basic training the best the institu-

tion had, in quality of instruction, equipment, largely increased laboratory time, and a universal recognition that the important course to the department, as a whole, is general chemistry. It might be said, and some progressive administrators and teachers *do* say, that a chemistry department can be rated in terms of its general chemistry. We can almost say that there is no department of chemistry in this country that can be classed as a great or strong department whose general chemistry is not the best course that the department can secure by having experienced teachers to handle the work, having excellent equipment, modern laboratories, and a sufficient number of laboratory hours to do the work required. Unfortunately some few large institutions still have not changed their general chemistry to meet the new conditions. One has only 4½ hours a week for one year without a year of high school chemistry as a prerequisite; another has had its hours reduced by the board of trustees from five hours a week for a year to four (without a year of high-school chemistry as a prerequisite); this despite the strong protest of the administrative head and the entire teaching staff. This is certainly a mistake, a short-sighted policy, and a backward step by the board. Why should a body of business men who are not experts in this line, determine the policy of a department and neglect the advice of those who do know and have the good of the department at heart?

The greatest confirmatory proof of the statement made that a department of chemistry is great in proportion to the quality of its general chemistry is found by making a list of those institutions, which rank highest in this country from the point of view of research and of the training of its students, and comparing the effort expended in making general chemistry the very best. It will be found that the institutions of the highest rank have a first class course in general chemistry with six hours a week or more in laboratory work for one year. Those who do not take this ever-growing and modern point of view will surely become decadent departments.

The ever-growing importance of chemistry will demand an ever increasing efficiency. I predict that the time is not far distant when an investigation carried on by such an organization as the Carnegie Foundation similar to that done in the medical schools[1] of this country and Canada, will be instituted, and a result similar to that of this report on low grade medical schools, viz., an elimination of those institutions who do not do so good chemistry work. When such a report is published, those low grade institutions will cease to teach chemistry, because the students, knowing the true state of affairs will either not elect chemistry, or if interested, will go elsewhere where the subject is properly taught.

Before taking up the working of the "Freas System"[2] in the general chemistry laboratory, we wish to review briefly the existing methods now in use.

First, the old side-shelf reagent system which is very common, in fact now exists in most college laboratories in this country. Nothing can be said in favor of this system, as it has no virtues, and possesses innumerable evils. It is wasteful, expensive, untidy; almost impossible to prevent contamination of chemicals and is one of the main sources for wasting students' time and encouraging petty theft. In a chemical laboratory of one of the oldest universities in this country, where the side-shelf reagent scheme is used, a student needs one particular chemical five times during the course. For this one chemical alone he has to walk five hundred feet during the term. One hundred and forty chemicals are used, and it can readily be seen that a large amount of time will be wasted if he makes but one trip for each chemical. One trip to the side shelf for these chemicals means a walk of thirteen miles, while a double trip, which is most common, would amount to a twenty-six mile walk or equal to two or more laboratory weeks work. The director of this department told me that while

[1] Published in a report to the Carnegie Foundation on Medical Education in the United States and Canada by Abraham Flexner, Bulletin Number 4, 1910.

[2] SCIENCE, May 30, 1919.

taking these laboratory walks to the side shelf the student was deep in chemical thought and therefore it was a good thing. My observation of students in this laboratory and elsewhere leads me to believe that this director seldom enters the chemical laboratory, and therefore does not know the true state of affairs, nevertheless he regards himself eminently qualified to pass on such matters.

One of the most serious objections to this system is not cost, or waste of students' time, but the slovenly habits which a student of a necessity acquires.

In going to a 2-kilogram bottle of potassium iodide, for example, to get 2 grams of that salt the neat and quantitative idea of general chemistry is absolutely lost, although he may be assigned to some general quantitative experiments during the course. Thus, the orderly habits which are so necessary to a good chemist, are not formed when they should be formed, viz., during the early days of his chemical training.

I can not pass without referring to a common sight a few years ago in another large laboratory in this country. Large bottles of chemicals were put on side tables for student use. A cheap porcelain pan balance and a box of weights stood nearby. Suppose a student needs 5 grams of potassium bromide, should it be a bit lumpy, a rusty ring stand served to break up the lumps. A handful of the expensive chemical was then placed on one pan of the scale and the old and corroded 5 gram weight on the other pan. The student brushed the excess chemical from the pan to the floor till he had remaining approximately 5 grams. In the morning I have seen the cleaners sweep up dust pan after dust pan full of valuable chemicals from the floor near this side table. There was seldom any supervision on the part of the instructor in charge when the students were getting their chemicals or conditions would probably not have been so bad. This institution of course was not famous for turning out great chemists and a sudden change in administration alone would save its life. To-day this same laboratory is one of the most up-to-date and progressive laboratories in this country. Few of the former teaching staff now remain, as they were too firmly fixed in the old ways to make reform possible.

The next step in the evolution of the handling of students' chemicals and supplies was to give him a kit of apparatus and place on his bench in the laboratory all the chemicals needed for the day or week. If two men worked on opposite sides of a bench this one set was sufficient for them both, *e. g.*, in a laboratory which holds 28 students at a time 14 such kits are used. This was a very great advance over the side-shelf reagent plan, as it eliminated a great deal of walking on the part of the student, thus enabling him to do much more work. One institution made this change and at the same time enormously increased the amount of assigned laboratory work per afternoon. While this scheme is a great improvement, it has still serious drawbacks. Chemicals are still bound to be mixed up and contaminated no matter how watchful the instructor may be. Certain chemicals are always running short, as some student will take more than his share even though a cheap balance is provided for every two men, so that weighing out approximate amounts is an easy and rapid matter.

Theft of chemicals is still possible, as no instructor can watch 25 students all at one time, and even if he could do so, he can not determine whether chemicals placed in a test tube were for laboratory or home use; this method while cheaper than the first is still expensive, because the students are bound to waste chemicals when they are handy and do not cost them anything; the bottles are always getting mixed up and out of place; and finally it entails enormous amount of work on the stock system or for the instructor, out of laboratory hours, as well as a certain amount of the same kind of stock work during the laboratory period.

In one institution[3] where this plan has been in operation for the past five years a special

[3] Professor C. D. Carpenter's laboratory at Teachers' College, Columbia University.

staff of women is employed to make up sets of common chemicals, place them on the students' desks and on completion of this set of experiments, refill the bottles and place them away for the next time needed. One equipping a week generally suffices for a laboratory with several fillings of certain bottles. This plan relieves the instructor of stock duties, but is still open to the objections named above.

In another large institution with nearly 1,000 students in general chemistry, the change was made from the side-shelf plan to the method of supplying a student chemicals at his bench. Here again the amount of laboratory work was nearly doubled per afternoon, because of the more efficient handling of supplies and a corresponding saving of students' time. Unfortunately in this institution no provision was made for the putting up of sets of chemicals by the stock division and the entire teaching staff in this division became stock keepers and more energy was expended in filling bottles than in giving instruction. This overload was at once observed in a decreased efficiency of work on the part of the instructor, and strenuous appeals have been made to the administrative head to relieve a most intolerable condition. Much cheaper and less highly trained people can and should be secured to fill bottles and do this kind of work, and a director of a chemistry department is short-sighted indeed who insists on his teaching staff spending most of their time doing the work of a ten-dollar-a-week boy. It can be clearly seen that the efforts to improve the work in general chemistry in this particular institution are not appreciated, or conditions will be improved at once and the teacher given a chance to perfect himself in his chosen profession and give the students the benefit of his experience. The failure of an executive to encourage and aid progressive teachers in the development of new ideas along this line is not only a very great injury to the teacher concerned, and to the institution as well, but is professional suicide to the administrator himself. It has been shown that the second scheme is an improvement over the first, but is still open to objections, and while it possesses considerable merit, it has many fatal defects.

The third plan, viz., the Freas System in the general chemistry laboratory has all the virtues of the second plan and none of its defects. In fact, when this plan is properly installed and carried out, it leaves little to be desired for both student and instructor.

The plan in brief is to give the student on his first day all the apparatus and chemicals he will need for that course. The student after the payment of all fees and deposits reports to his instructor and is assigned in writing to a bench in the laboratory. He takes this assignment to the stock room and receives his apparatus and chemicals in heavy cardboard or metal boxes and takes them to his bench. This kit he arranges in his desk as stated in his directions If he has properly arranged his material he can quickly find any special chemical or piece of apparatus and is ready for work within two hours of starting. He puts his own padlock on his bench and he alone is responsible for its contents till his course is completed at the end of the term. He has received just enough of each chemical to perform the experiment plus a slight excess to offset any possible unavoid able accident. Should he be careless and not perform his experiment properly he must go to the store room and sign for more chemicals which of course are charged to his account, and later deducted from his advance breakage and "excess chemicals" deposit. Right here it should be stated for clearness that the student is charged for all apparatus and chemicals, but is given as a free allowance the average value of the chemicals used by his class. If he has a modern bench, with a hod in front of him, all walking about has been eliminated, and the amount of laboratory work that he can do per afternoon can be nearly tripled over that possible under the side-shelf reagent scheme.

Contamination of chemicals is impossible under this plan, as each container is plainly labelled and is under the personal care of the student interested.

The factor of expense has been reduced to the minimum, as there can be no waste from

the department's point of view and the student has received as a free allowance, sufficient chemicals for his needs, providing he is the average student and exercises moderate care. The possibility of theft is withdrawn absolutely, as the kit belongs to the student, to do with as he wishes, and no student will or can steal his own things. The prices on his list are selected from the most recent catalogue of the largest apparatus house in his vicinity, so he has no temptation to take things home because he saves by so doing. In fact in many cases an apparatus house will sell him things somewhat cheaper. Theoretically the student can if he wishes get all his kit elsewhere, and this is encouraged, as it will save the department the trouble of furnishing it, but the student would much rather take the department kit which is all ready made up and easy to procure, and is just exactly what he needs in his course.

This system takes out of the hands of the teaching staff all cares in regard to apparatus and chemicals, as this side of the work is handled by a trained body of men and women who soon learn to do the bottling of chemicals and the assembling of the same into kits, with the greatest speed and accuracy. In rush times, student help makes possible the doing of a great deal of work in a short time and is a benefit to both the department and the student.

The Freas System is just as helpful and as easily installed in a high school as in a technical school, college or university laboratory.

Of course each student must have the average size bench, viz., about 8,000 cubic inches, in order to hold this kit. Many laboratories give the student more space than this, but if one takes the measurement of a student bench in high schools and colleges all over this country, the figure 8,000 cubic inches is about the average. Unfortunately in a few good institutions circumstances over which the departmental authorities had no control, forced a reduction of students' bench space. More students were crowded into the laboratories than the benches were able to accommodate, and it seemed at that time wise to begin to reduce the size of the student bench. In one case this went on until a student finally had but one drawer of about 400 cubic inches. In such a space only the most meager equipment can be placed, and the student of course suffers through lack of apparatus and an enforced walking to the storeroom and back for every little thing he may need. The pendulum has started to swing back, and I have no doubt that before long this department will restore the normal 8,000 cubic inches.

Some may say that the cost of installing this system is prohibitive. This is not so, as can be shown by actual figures in institutions using it. Others may wish to know where this scheme has been tried out for a sufficient length of time as to insure it being out of the experimental stage. The department of chemistry of Columbia University in New York City has been using this system for the past eight years with an ever-increasing satisfaction to all concerned, in all divisions of the department.

There is no question but that the Freas System is the cheapest, everything considered, most efficient, and up-to-date method of handling students' supplies yet devised. If a chemical department wishes quality of work above everything else, then this system will be an enormous aid to both student and instructor; but if quantity is the object to be obtained, then it does not matter so much, as quality of work is probably given but little thought. If a department must handle large numbers of students and wishes quality of work as well, then there is no question but that the quicker the authorities investigate the Freas System the better. No unprejudiced man can see this system in operation without feeling that he will not be satisfied till it is as speedily as possible installed in his own department.

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